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Stay off-pump and do not touch the aorta!

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This editorial refers to ‘Protecting the brain from gaseous and solid micro-emboli during coronary artery bypass grafting: a randomized controlled trial’[†], by T. Gerriets *et al.* on page 360

One of the major drawbacks in contemporary on-pump coronary artery bypass surgery is the inherent risk of intraoperative stroke. In addition, neurophysiological dysfunction and neurobehavioural changes have been reported in variable frequencies following on-pump bypass surgery. Cardiopulmonary bypass (CPB) causes a systemic inflammatory response, haemodilution, change in vascular resistance, absence of pulsatile flow, and large volume shifts. As a result, temporary cerebral oedema can be seen in magnetic resonance imaging (MRI) studies early after on-pump bypass surgery and has been identified as the substrate for what was termed ‘pump head’ in the past. Refinements of CPB circuits using biocompatible surfaces, the use of less traumatic oxygenators, and the addition of filters as well as the establishment of standardized perfusion protocols have improved the results of on-pump surgery. Despite these advances, CPB remains one major source for gaseous microembolization.^{1,2} Retransfusion of shed mediastinal blood during on-pump surgery has long been recognized as an additional source of embolization by fat particles and activation and derangement of the clotting cascade.

Manipulation of the ascending aorta such as partial or total clamping and cannulation required for installation of CPB can cause additional solid emboli especially in the presence of atherosclerotic disease.^{3,4} Numerous studies have shown embolic showers in transcranial Doppler during cannulation and clamping and declamping manoeuvres. The release of particulate emboli correlates in particular with the release of the aortic cross-clamp.⁵ Gerriets *et al.* have reported a randomized controlled trial to demonstrate the impact of two different methods to decrease the embolic load during on-pump bypass surgery with partial aortic clamping in a low risk group of patients.⁶ As protection devices the Embol-X was used in 43 patients and a dynamic bubble-trap (DBT) in 50 patients. A control group ($n = 50$) received no protection device.

The primary endpoint was the 3 month cognitive outcome which showed better short-term memory and executive functioning in the DBT group despite a general decline in the composite cognitive score in all groups. This finding, albeit statistically significant, may have only limited clinical implications, as numerous studies have demonstrated complete recovery of peri-operative neurocognitive decline over time. Intra-operatively, microembolic signals (MES) were recorded with transcranial Doppler in only 63% of the patients using transcranial Doppler sonography of the middle cerebral arteries. While the total number of MES was lower in the DBT group, it was not different for the Embol-X group as compared with controls. The numbers of event-related MES were higher with aortic clamping and filter insertion, but lower with declamping in the Embol-X group. In a multi-institutional randomized study on 1289 patients the efficacy of the Embol-X intra-aortic filter to reduce the embolic burden was demonstrated by the high capture rate (96.8%) of particulate emboli. Despite successful filtering of some solid emboli, there was no difference for either the composite endpoint or the individual endpoints including stroke for the treatment group and the control group.⁷ This is in line with the finding of Gerriets presented here who could not demonstrate a protective effect of the Embol-X filter device.⁶

In 17/125 patients (13.6%) undergoing post-operative cerebral MRI, asymptomatic acute ischaemic brain lesions (diffusion-weighted imaging lesions) were detected. There was no difference between groups, indicating that emboli do occur despite the use of protection devices, and visible lesions in MRI do not necessarily correlate with neurocognitive outcome 3 months after surgery. This confirms previous studies that have shown no association between new focal brain lesions and impaired neuropsychological performance and could not demonstrate a correlation between clinical variables and MRI findings. New ischaemic brain lesions on post-operative diffusion-weighted MRI *per se* do not appear to account for the mostly transient but sometimes persistent neurocognitive decline after on-pump bypass surgery.⁸

Unfortunately, the authors did not comment on the extent of aortic atherosclerotic disease within groups which largely determines the risk for solid emboli and peri-operative stroke. Other

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confounding factors such as peripheral artery disease, flow-limiting carotid artery stenoses, previous stroke, age, diabetes, hypertension, history of myocardial infarction, impaired left ventricular ejection fraction and chronic renal failure have invariably been identified as potential risk factors for stroke unrelated to the type of surgery. These confounding factors create a 'background noise' that is difficult to eliminate when discussing procedure-related risks. Extended CPB times, high transfusion requirements, peri-operative use of an intra-aortic balloon pump, as well as post-pump low cardiac output and atrial fibrillation are independent determinants for post-operative stroke and may also contribute to the temporary neurocognitive decline following on-pump surgery.

While some risks such as gaseous embolization can be diminished by the use of arterial line filters, adding devices is not always without risk. For the Embol-X endoaortic filter endothelial disruptions were found more frequently by epiaortic scanning in a large multicentre trial.⁷

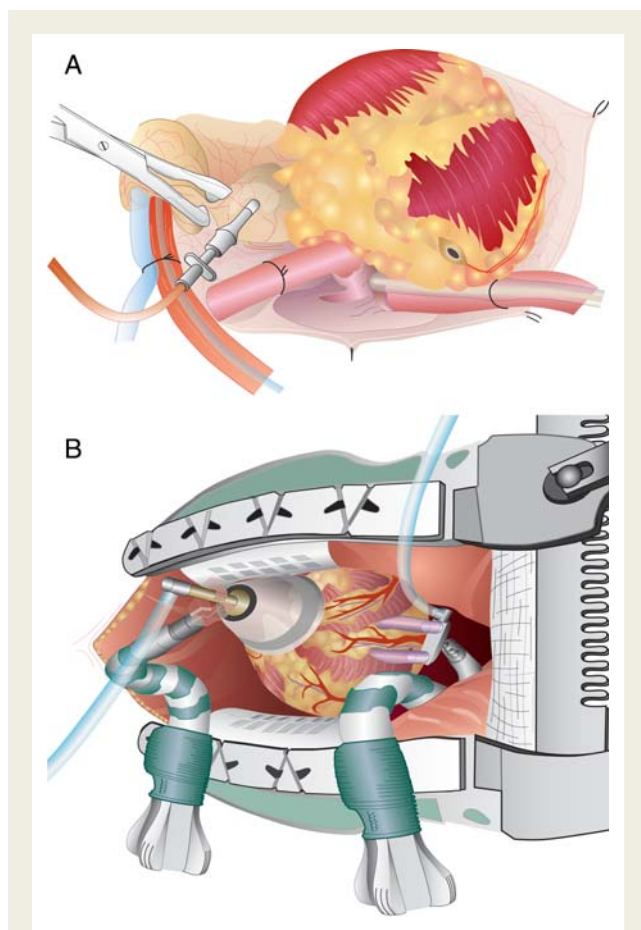


Figure 1 Standard coronary artery bypass procedure requires aortic cannulation and clamping. Both manoeuvres can cause emboli especially in the setting of an atherosclerotic aorta (A). For off-pump coronary artery bypass grafting (B), the target vessel is exposed applying a vacuum-assisted stabilizer that allows for local immobilization (B). Cardiopulmonary bypass is not required since the procedure is performed on the beating heart.

In contrast, novel dispersion aortic cannulae or different cannulation sites can potentially reduce the number of particulate emboli by decreasing the 'sandblasting' effect of a highflow cannula facing the wall of a calcified ascending aorta. Continuing this rationale, avoiding aortic manipulation and CPB altogether seems very attractive. Off-pump coronary artery bypass surgery can potentially reduce the embolic load during coronary bypass surgery by eliminating the need for aortic cannulation and aortic cross-clamping (Figure 1). Avoidance of CPB reduces the systemic inflammatory response and likelihood for gaseous emboli. Some studies have found a decrease in the risk of stroke and cerebrovascular incidents after off-pump coronary artery bypass as compared with on-pump bypass surgery, especially in high risk groups.^{9,10} Aortic manipulation can be avoided altogether if all arterial grafting is performed off-pump and no grafts to aorta anastomoses are performed (Figure 2). Most studies that could not find a difference between neurological complications after on- and off-pump bypass procedures did not apply total arterial grafting and used site-biting clamps for performing the proximal anastomoses. However, even when a 'no touch technique' and the exclusive use of T-graft techniques are rigidly applied, the risk of peri-operative stroke cannot be completely eliminated,^{11,12} and is most probably related to an underlying risk defined by the general health condition of the patient. Interestingly, this also applies to interventional revascularization procedures. According to a recent meta-analysis the rate of procedural stroke (reported in 15 randomized trials) is unarguably higher after coronary artery bypass grafting (1.2%) than after percutaneous coronary intervention (PCI) (0.6%) but is certainly not negligible after PCI.¹³ The SYNTAX trial has highlighted once more the importance of peri-operative stroke for the overall results after revascularization procedures.¹⁴

Interestingly, in the bypass group, half of the events occurred peri- rather than intra-operatively and may be related to the high incidence of peri-operative atrial fibrillation and the lesser use of antithrombotic drugs in the bypass group.

To the best of our knowledge today, the combination of off-pump surgery and all arterial grafting may be the surgeon's best tool to avoid some but not all neurological complications after bypass surgery. Prophylactic antiarrhythmic and antithrombotic treatment as well as aggressive treatment of peri-operative atrial fibrillation may further reduce the incidence of neurological events after bypass surgery.

Conflict of interest: none declared.

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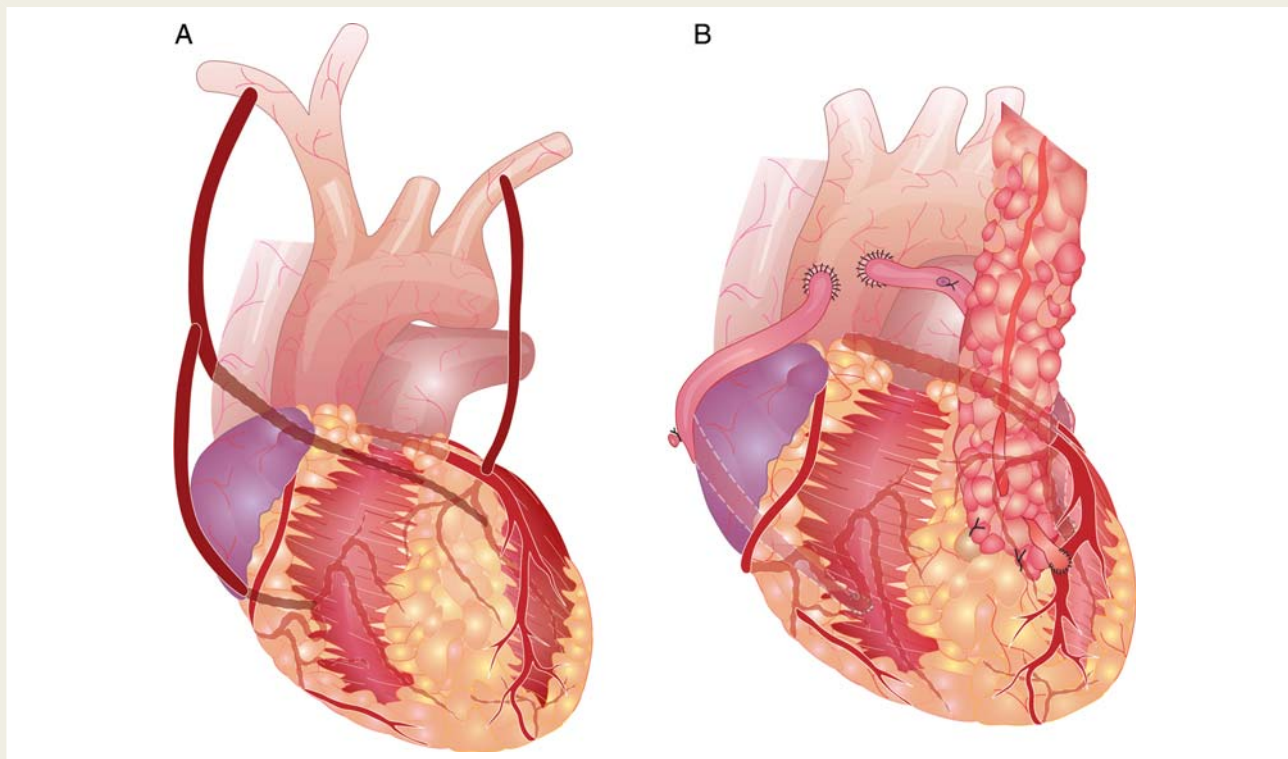


Figure 2 Total arterial grafting using both internal thoracic arteries and the radial artery allows complete revascularization without the need for an aortic anastomosis (A). If this procedure is performed on the beating heart (a), the aorta is not touched ('no touch technique'). If venous bypass grafts are used (B) manipulation of the ascending aorta is required to perform the proximal bypass graft anastomoses.

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